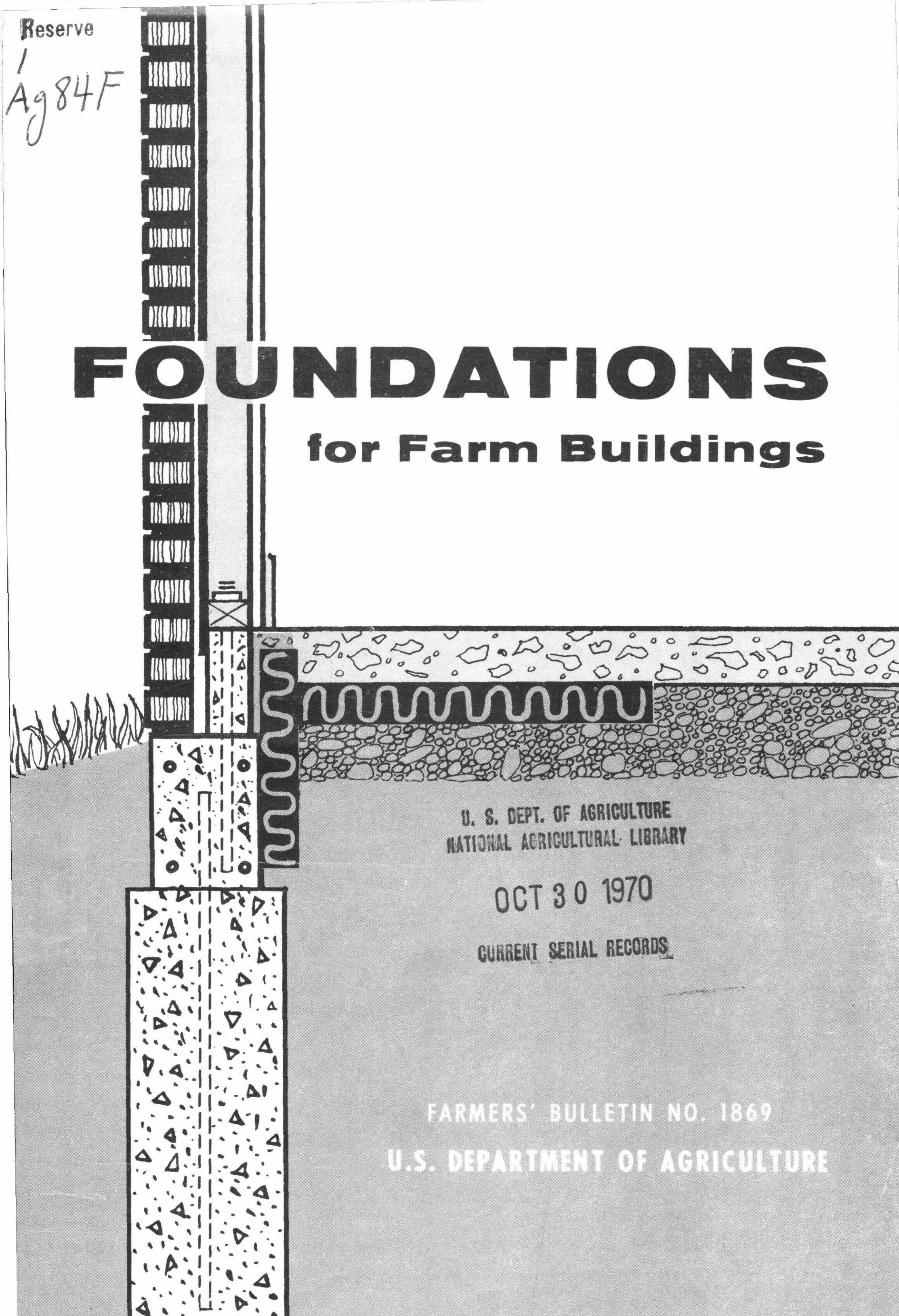
FOUNDATIONS

for Farm Buildings



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CONTENTS

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FOUNDATIONS

for farm buildings

Prepared by Agricultural Engineering Research Division
Agricultural Research Service

Each new foundation for a farm building must be designed specifically for the building it will support and for the site it will occupy. If the building is going to be an expensive, permanent structure, it is probably better to hire a local engineer or builder to design and construct the foundation than to try to do it yourself.

The well-designed and well-built foundation must resist the forces acting on it. They are—

- The weight of the building and the supporting, or bearing, value of the soil.
- Soil movement caused by a change of moisture content in the soil, and by heaving during freezing and thawing of the soil.
- The uplift and overturn forces of wind on the building.

If the building has a basement, the foundation also resists the pressure of the outside soil on the basement walls.

Failure to resist any one of these forces will cause the foundation to crack, settle, or be moved in the ground.

When you select the site for your building, do it carefully. If it is possible, pick a site on a slight elevation with good drainage and firm subsoil.

After you have selected your building site, you will want to consider the various types of foundations.

TYPES OF FOUNDATIONS

Several types of foundations are used for farm buildings. They are—

- Continuous walls.
- Basement walls.
- Step foundations.
- Pier foundations (either precast or built in place).
- Pole foundations.
- Grade beams.
- Slab foundations.

Continuous Walls

Continuous wall foundations are used for buildings that are subjected to heavy loads, for buildings that must be warmed, and for buildings that must be rodent proof. They are built out of either concrete or unit masonry (concrete block, brick, clay tile, or rubble stone).

In general, foundation walls that are 8 inches thick and are built of concrete, concrete block, brick, or clay tile are ample for wooden buildings that are no heavier than a farmhouse. Rubble stone walls, for the same weight building, must be 12 to 16 inches thick.

Even foundations that are well designed and have footings of proper size and depth can fail if the sills of the building are not sufficiently and properly fastened to the foundation.

The sills of a frame building can be broken or torn loose from the foundation if the anchor bolts are too small, are not embedded in foundation far enough, or are spaced too far apart (fig. 1).

Light, frame buildings are anchored to continuous foundations with ⅝-inch bolts spaced 8 feet apart and extended 12 inches into concrete walls or 24 inches into unit masonry walls.

The cores of hollow masonry units (concrete block and clay tile) are filled around the anchor bolts with concrete. Two rows of hollow units are filled under girders or other concentrated loads. (Crumpled paper stuffed in the hollow

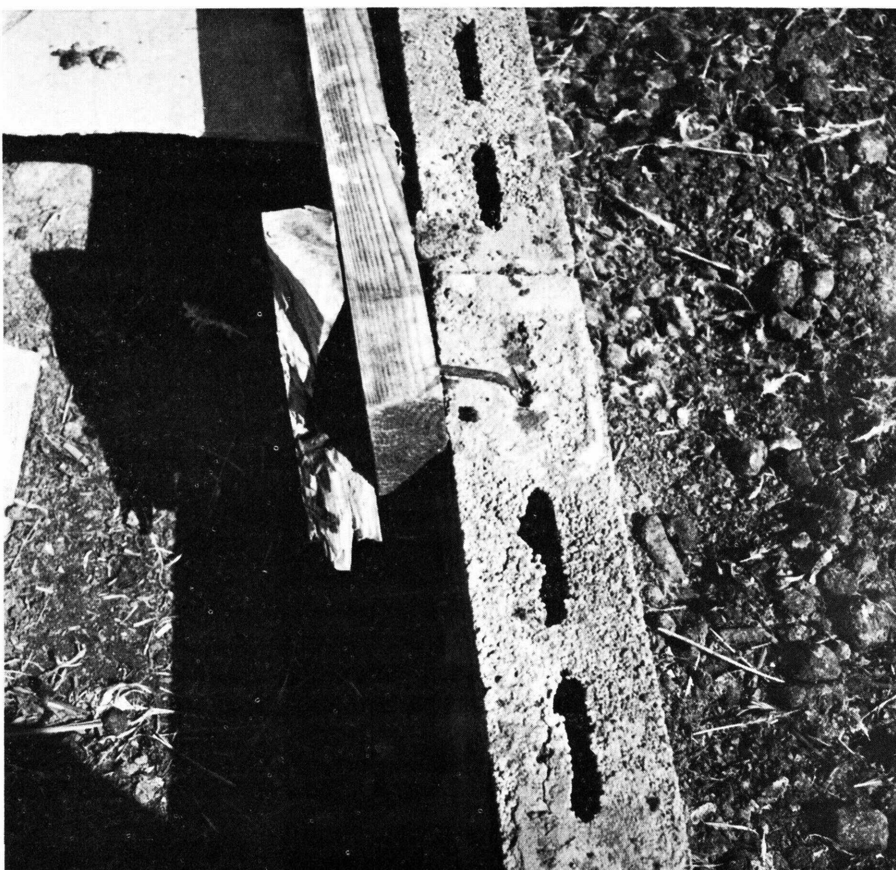

Figure 1.—The sills of a frame building can be broken or torn loose from the foundation if the anchor bolts are too small, are not embedded in the foundation far enough, or are spaced too far apart.

Foundations for buildings with arched roofs or rigid frames, or for storage buildings in which the stored material presses outward on the walls, require buttresses. If the foundation wall of an ordinary building is unusually high, buttresses may be required to resist wind overturn.

cores prevents the concrete from dropping lower than needed.)

The foundation wall must be reinforced at the corners and at the junctions of the outer wall and inner walls to prevent cracking. When hollow units are used for foundations, special joint reinforcement below grade level may be used to counteract the pressure of the soil on the foundation.

A concrete rodent shield is shown in figure 2. The shield is about 1 foot beneath the ground and extends about 1 foot horizontally from the building.

The crawl space (beneath the floor of the building and enclosed by the foundation) should be well ventilated to reduce humidity. The vent area should be at least 1 square foot per 15 lineal feet of foundation wall. Ventilators that can be closed during the winter are best.

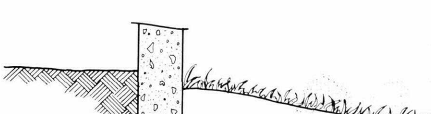

Figure 2.—A horizontal shield on the outside of the foundation wall discourages burrowing rodents.

Basement Walls

Basement walls usually serve both as bearing and as retaining walls. As bearing walls, they support the building; as retaining walls, they resist the lateral pressure of the outside earth.

A height of 6¾ feet from basement floor to first floor joists is considered a minimum-convenience height. Greater height may be necessary to accommodate a furnace, warm-air ducts, and plumbing, and still leave adequate head room.

Basement wall thickness should be determined by a structural engineer.

Unless areaways (fig. 3) are provided, the top of the foundation wall should be at least 2 feet above grade to permit windows in the basement for light and ventilation.

Step Foundations

A stepped foundation is a variation of a continuous wall foundation and is used where the ground slopes or where there is a basement under only part of the building.

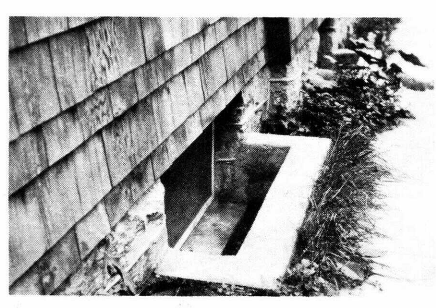

Figure 3.—Areaways permit windows in the basement when the outside grade is high. Do not pave the bottom of the areaway unless you provide it with a piped drain.

The foundation is stepped down gradually (see fig. 4), to keep the footing on solid ground and to avoid undermining the higher part of the foundation with excavations at the time of construction.

Where the foundation is built on sloping rock, level steps are cut in the rock. These steps prevent the foundation from slipping. Slight slopes are sometimes merely heavily chipped; sometimes they are doweled. Where outcroppings of rock have been exposed to weathering for some time, the surfaces are likely to be decomposed or loose. This loose surface must be cut away.

For average soil, a vertical step (*V* in fig. 4) of not more than 2 feet in a horizontal distance (*H* in fig. 4) of 4 feet is generally satisfactory. In any case, the horizontal distance should be over 2 feet and the vertical step should be less than three-fourths of the horizontal distance. For example, if

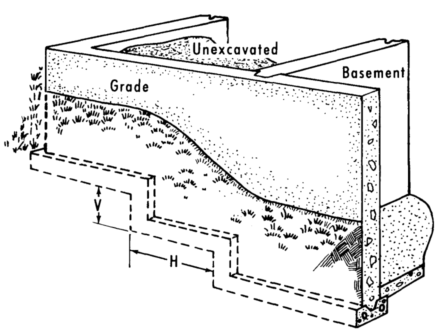

Figure 4.—A stepped foundation can be used where the ground slopes or where there is a basement under only part of the building. In either case, the horizontal distance, *H*, must be over 2 feet, and the vertical step, *V*, must be less than three-fourths of the horizontal distance.

the horizontal distance is 6 feet, the vertical step should be less than 4½ feet.

There should be a projection on the vertical part of the step (see fig. 4). It should be as wide as the footing on the horizontal part of the step and at least 6 inches thick.

Pier Foundations

Pier foundations are more economical than continuous wall foundations. Standard piers are built of brick, concrete, rubble stone, and hollow masonry filled with concrete. More slender piers can be made of reinforced concrete or masonry.

If you require a warm building floor, the space between the outside piers can be closed with curtain walls.

Pier spacing is largely a matter of economy and building weight. Since beam strength varies inversely as the square of the beam span, a beam spanning 6 feet is four times as resistant to bending as the same beam would be if it spanned 12 feet. Closer spacing of piers is usually more economical than using heavier beams.

Concrete and concrete-block piers that are 3 to 4 feet high must be reinforced at each corner with vertical steel rods ⅜ inch in diameter. The rods should be at least 2 feet long and hooked on the ends. One end is buried 5 inches in the footing (fig. 5, *A*) to bond the pier to the footing; the rest of the rod is extended into the pier.

Concrete and unit-masonry piers 4 to 6 feet high need additional reinforcing as shown in figure 5, *B*. The advice of a structural engineer is required for reinforcing larger piers.

It is easier to reinforce 4- to 6-foot piers with two-piece reinforcing rods than with one-piece rods that run the full height of the pier. Short dowels of reinforcing rod are set into the footing so that they extend 18 inches above the footing (fig. 5, *B*). The dowels are set so that they will aline with the corresponding pier-corner reinforcing rod. The dowels are wired to the pier-corner rod.

Bolts, ⅝ inch in diameter, anchor the building to the piers. The bolts, with a hook bent in the lower end, are set 12 to 18 inches into piers of concrete and 3 feet into piers of unit masonry. They extend above the pier far enough to fasten down the building's sills or girders.

Figure 5, *C*, shows a method of anchoring wood posts to piers.

Buildings with pier foundations are more frequently victim of wind uplift than buildings with other types of foundations. Usually this is because the piers are not heavy enough and are not sufficiently anchored in the ground.

A pier footing should move at least 1 cubic yard of soil if it is pulled from the ground. It should be at least 15 inches square and should be at least 2 feet deep. The footing, pier, and building sill (or post) must be securely fastened together.

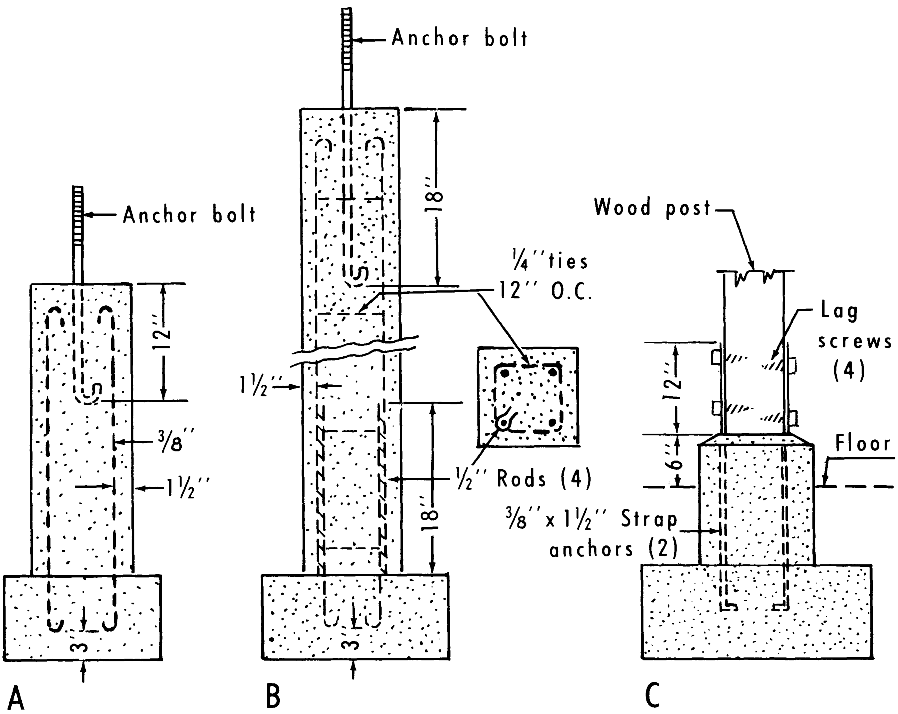

Figure 5.—*A*, Method of reinforcing and anchoring short piers; *B*, method of reinforcing larger piers (note how the dowels are wrapped to the reinforcement with baling wire); *C*, method of anchoring wood posts.

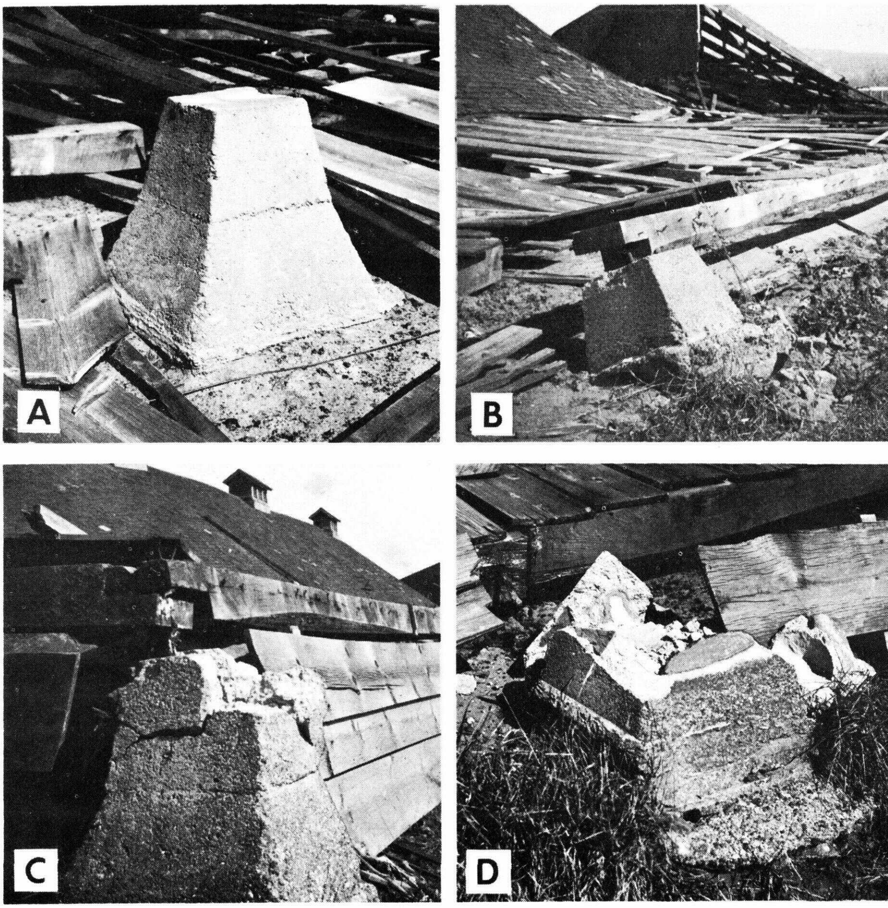

Figure 6.—*A*, This well-built pier was securely doweled to its footing—but the anchor bolt to hold the sill was omitted; *B*, the anchor bolt was supplied for the sill—but the footing was made in a shallow, round hole; *C*, the anchor bolt did not extend into the pier far enough and, when under strain, broke out of the pier; *D*, the concrete for this pier was made with aggregate that was too large for the size of the pier.

Pole Foundations

Pole foundations are economical and sturdy. Pressure-treated wood poles—7 to 10 inches in diameter and extending from concrete footing pads to the roof of a building—anchor the building and resist overturning and racking wind forces.

The depth to which the poles are set, the type of backfill around the poles, and the type of anchorage on the poles determine the building's resistance to wind forces.

Soil type, soil moisture, and quality of backfill tamping determine the foundation-design load that can be carried by the poles.

Usually a hole 20 inches in diameter affords adequate room for the pole and concrete footing pad, gives some room for movement of the pole to obtain proper alinement, and does

not cramp the tamping tool used for packing the backfill. In most areas, poles should be set 5 feet deep.

A backfill of well-tamped, crushed stone is better than a backfill of earth. A pole set in crushed stone will move about one-half as much as a pole set in earth. A concrete backfill is required when movement of the pole at the ground line cannot be tolerated.

Poles set 5 feet in any type of backfill that is reasonably well tamped will hold against normal wind uplift.

Grade Beam

A grade beam is a rectangular, reinforced-concrete beam that serves as a continuous foundation. It does not extend into the soil more than a few inches, but is supported on reinforced concrete piers.

Where soft soil overlays a more compact soil, a good foundation can often be secured with a grade beam. Holes are drilled through the soft soil and the holes are filled with reinforced concrete piers. These piers support the reinforced beam in the soft soil.

The grade beam itself extends about 8 inches above grade and about the same distance below grade. It is placed over a fill of loose gravel, cinders, or similar porous material that will drain water from beneath the beam.

The concrete piers are 10 inches in diameter, and spaced 8 feet on center for one-story buildings and 6 feet on center for two-story buildings.

The piers are reinforced with ⅝-inch reinforcing rod that extends through the grade beam (fig. 7).

The cross-sectional size of the grade beam for the average one-story farmhouse should be about 8 by 16 inches. The size for buildings other than dwellings will depend on the weight of the building and the length of the beam, and should be determined by an engineer or builder who is familiar with reinforced concrete design.

Slab Foundations

Slab floors and slab foundations are different. Slab floors are cast independently of the foundation and are usually isolated from the foundation with 2 inches of rigid insulation.

Slab foundations are both foundation and floor, and are cast as one reinforced unit. The building is anchored to the slab with ⅝-inch bolts that are set in the slab when the slab is cast. The weight of the slab anchors the building to the ground.

The design of a slab foundation—its dimensions and reinforcing—depends on the weight of the building, the type and drainage of the soil, and the climate. Even for light structures, slab foundations should be designed by a structural engineer who is familiar with your local conditions.

The soil under the slab must be compacted to prevent the slab from settling and cracking. If earthfill is required under the slab, or under a part of it, the fill must thoroughly settle and be as firm as undisturbed soil before the slab is poured. The soil or fill under the slab should be covered with 4 to 5

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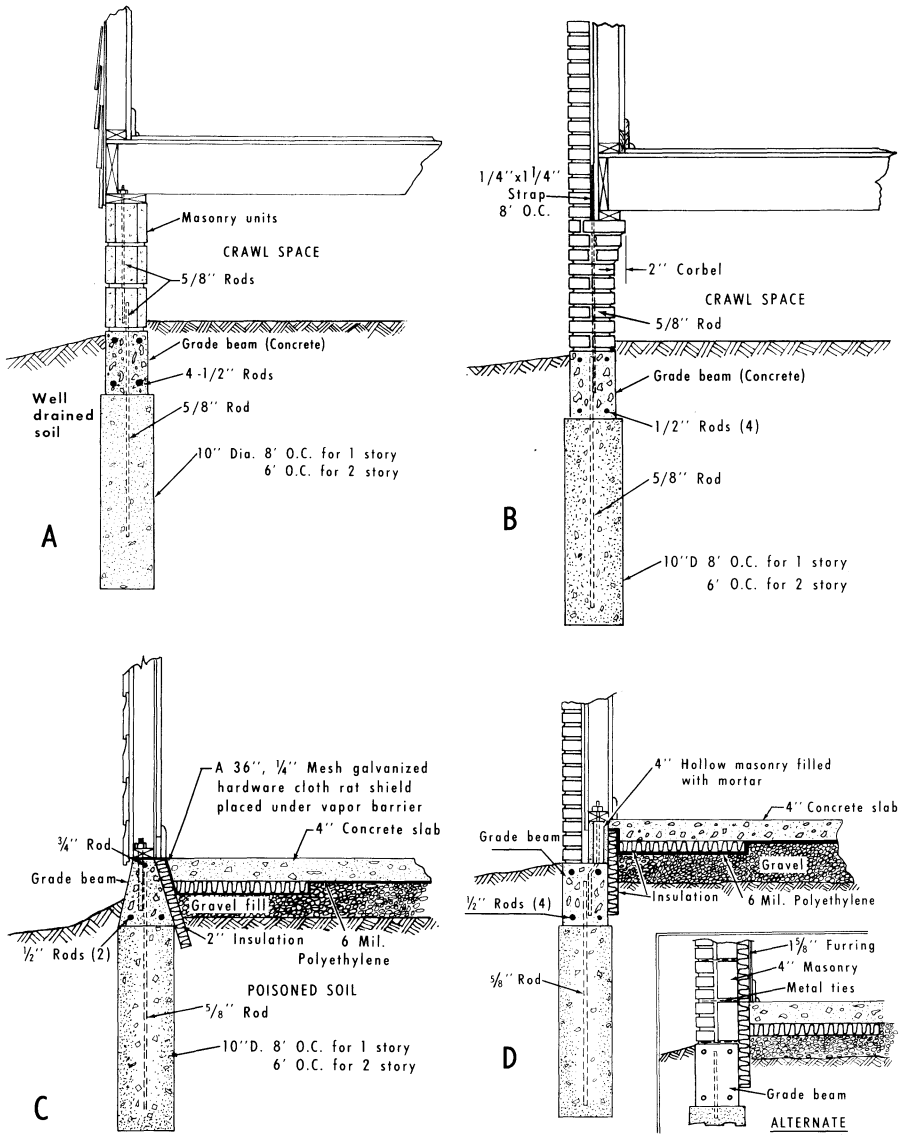

Figure 7.—*A*, **Grade beam for a frame house with a crawl space;** ***B*****, grade beam for a brick-veneer house with a crawl space;** ***C*****, grade beam for a frame house with a slab floor;** ***D*****, grade beam for a brick-veneer house with a slab floor.**

inches of gravel, topped with sand, to give a well-drained subgrade to the slab.

FOUNDATION MATERIALS

Solid concrete walls and brick walls have a high resistance to crushing. They are best for buildings with heavy loads.

Hollow units—clay tile or concrete block (except cinder block)—are strong enough for foundation walls for ordinary buildings. Cinder block is too porous to be suit-

able below ground and in direct contact with the damp earth.

Alkaline soil deteriorates concrete; advice for protecting concrete from the effects of alkaline soil can be obtained from your State agricultural college or university.

Brick and clay tile are unaffected by alkaline or acid soil.

Freezing will damage concrete if the concrete freezes before it has set and cured. Unit masonry must also be protected from freezing until the mortar is cured.

Concrete

Concrete is the best material for foundations. Directions for making concrete footings and walls, and methods for building forms are given in Farmers' Bulletin 2203 "Use of Concrete on the Farm."

In general, a 1:3:5 concrete (1 part cement, 3 parts sand, and 5 parts gravel) is used for foundation walls and footings. A 1:2½:3½ mix is used where watertightness is essential, as for basements, or where the concrete will be reinforced with steel.

If some unmuddied water is standing in the trenches, use a stiff mixture of concrete. Stiff concrete will displace the excess water.

When it is necessary to pump water out of the foundation trench to keep the trench from flooding, pour the foundation with stiff, high early strength concrete, especially that part of the wall below water level.

Concrete construction is only as good as the forming used. Construct plumb, square, and level forms. The forms must have sufficient strength to resist the weight and stress of wet concrete.

The sleeves for pipes, blocking for windows, anchor bolts, and other inserts must be placed in the forms before the wall is poured. Place them carefully; it is nearly impossible to change them after the concrete sets.

Basement walls are poured as one unit to above grade, especially in wet soil. When the size of the job or equipment does not permit this, make watertight joints between the old and new concrete.

Unit Masonry

There are several types of unit masonry for foundations—brick, clay tile, concrete block, and rubble stone.

Unit-masonry foundation walls and piers can fail at one or more of the joints between the units. This failure can be caused by weak mortar or by inadequate reinforcement and anchorage, or by both.

The brick and clay tile must be hardburned and uniform in size and

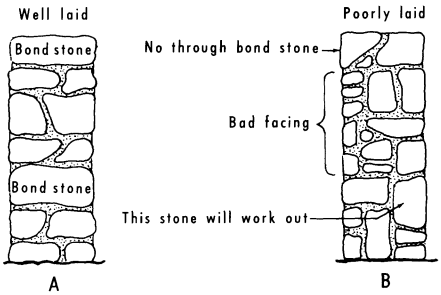

Figure 8.—A, Well-laid stone wall with bondstones extending through the wall; *B,* weak, poorly laid wall without bondstones.

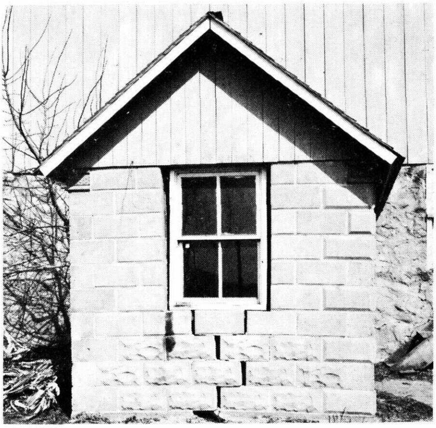

Figure 9.—**Frost heaving combined with a shallow footing to crack this building wall at its weakest point.**

shape. The concrete block should be suitable for underground use. The rubble stone must be hard and nonporous, and must not readily decompose when exposed to the weather. Irregular rock is difficult to lay and still maintain in good bond in the wall.

In unit masonry foundations, the mortar joints between the units must be completely filled to prevent water penetration. Water penetration can cause the wall to crack during freezing weather.

Mortar

Type M mortar—a high-strength cement mortar—is recommended for masonry foundations below grade and in contact with the earth.

Type M mortar is made with 4 parts portland cement, 1 part hydrated (type S) lime, 15 parts sand, and enough water to give the mixture a smooth plastic consistency.

A common defect of mortar is over-sanding, often caused by careless measuring. The sand proportion should never be less than 2½ times, or more than 3 times, the total volume of the cement and lime.

FOOTING DESIGN

Footings are projections at the base of the foundation. They distribute the weight of the building over an area larger than the foundation. They also anchor pier foundations to prevent wind from lifting the building.

In a well-designed foundation, the pressure of the building weight on the soil beneath the footings of the interior piers will equal the pressure of the building weight on the soil beneath the footings of the exterior walls.

To determine the proper size of foundation footings, it is necessary to know the characteristics and bearing value of the soil on which the building will be built and the weight of the building.

Soil Characteristics

Ideal foundation-bed soil will support the weight of the building, will neither swell nor shrink excessively, and will not heave from frost action. But such soil is rare. Dry, well-compacted, sandy clay soil probably comes closest to the ideal soil.

- Clay soils become plastic when wet. Under moderate pressure, wet clay will squeeze from beneath the foundation. But the bearing value of clay soil can be improved if it is drained and compacted by ramming in a layer of gravel or cinders.

Before building on dry clay, make certain it will not swell excessively when wet; some clays swell enough to lift buildings.

Frost heaving can be reduced if the foundation bed is below the frostline (freezing depth).

- Sand shrinks and settles when it becomes dry, and swells or flows when it becomes wet. Either change can make a foundation insecure.

If you build on sand, make sure the moisture content of the sand will remain constant; otherwise, the sand under the foundation will move.

- Avoid filled ground unless it is well settled. Filled ground generally causes trouble—the variation in fill depth and the different soils and waste materials used for fill cause the filled ground to settle unevenly. The different materials used for fill also have different bearing values.

- Spongy or peaty soils must have buildings specially designed for them. If you have spongy or peaty soil, hire a structural engineer to design both your foundation and your building.

- Occasionally a relatively thin layer of rock overlays soft clay or loose sand. Such a bed is unsafe for heavy buildings and for concentrated pier loads. Make sure that rock at your site is not merely a large boulder that might loosen under the weight of the building.

Soils differ in bearing power, and no soil behaves the same under all circumstances or has the same character at different depths below the surface. Therefore, before you build you should consult experienced engineers and builders in your locality.

You will have to investigate the soil to determine its characteristics. The best time to do this is during a wet period, either in the early spring or late fall.

Make preliminary probes with a ½- or ⅝-inch rod about 12 feet long. By driving the rod through the soil, you can determine the type, depth, and direction of slope of the underlying strata, and discover any buried boulders or rock layers.

If the preliminary probing indicates questionable conditions, investigate further. Dig to the depth of the proposed footing and then, using a soil auger, drill a hole 3 feet below that point. Note the various strata through the excavation and the hole.

Determine the safe load-bearing capacity of your soil as given below:

	Pounds per square foot
Hard rock	30,000
Soft rock	16,000
Gravel or coarse sand, well consolidated	12,000
Dry, hard clay or coarse, firm sand	8,000
Moderately dry clay or moderately dry, coarse sand and clay	4,000 to 6,000
Ordinary clay and sand	3,000 to 4,000
Soft clay, sandy loam, or silt	1,000 to 2,000

If water rises in the hole made for the preliminary probe, check with local engineers or builders. An adequate foundation could be expensive.

Building Weight

There are two types of building weight on a foundation—*dead loads*

and *live loads.* The dead load is the weight of the building itself—roof, floor, walls, foundation. The live load is the weight of the things housed in the building and the forces acting upon the building, such as persons, animals, furniture, grain, hay, wind, and snow.

Dead loads and live loads for estimating building weight are as follows:

Dead Loads (Approximate)

Roofs

	Pounds per square foot
Gable, sheathed with ¾-inch boards, supported 2 feet on center, 15-pound felt, 210-pound asphalt shingles	7
Gable, trussed, 5 feet 4 inches on center, 2- by 4-inch purlins, 28-gage corrugated steel	4
Gable, added weight:	
Asbestos shingles	3
Built-up roof	5
Slate	7

Walls

Stud framing, plates and sills, 2 by 4's 16 inches on center	2
Stud framing, 2 by 4's, 3 feet on center, 28-gage corrugated steel	2
Stud wall, plastered both sides	18
Stud wall, plastered one side	10
Stud wall, sheathed and sided with wood	7
Stud wall, ⅜-inch gypsum board both sides	6
Brick veneer	40
Brick, 9 inches thick	84
Clay tile, 4 inches thick	18
Clay tile, 6 inches thick	28
Clay tile, 8 inches thick	34
Concrete block, light aggregate, 4 inches thick	20
Concrete block, light aggregate, 8 inches thick	38
Concrete block, heavy aggregate, 4 inches thick	30
Concrete block, heavy aggregate, 8 inches thick	85

Floors

	Pounds per square foot
Double-on 2 by 10's, 16 inches on center	7

Miscellaneous Materials

Concrete or rubble stone, per inch of thickness	12
Gypsum board, ½ inch thick	2

Live Loads (Approximate)

First floor in dwellings	40
Second floor in dwellings	30
Attic floor in dwellings (habitable for storage only)	20
Roofs, in general	20 to 40
Assembly halls (where crowds collect)	100

Weight of Produce

	Pounds per cubic foot
Apples, carrots, potatoes	40
Beans, wheat, shelled corn	48
Ear corn, husked	28
Oats	26
Bran	16
Loose hay	4 to 5
Chopped hay or ordinary baled hay	10 to 13
Baled straw	8
Lime, fertilizer	55 to 60

Two general examples are given for estimating building weight. One example is for the one-story farmhouse shown in figure 10, and the other is for the barn shown in figure 11.

The weight on piers and walls must be calculated independently so that in neither case will the footing be too small. In general, the weight carried by a pier is the weight of the adjacent half of the beams (or girders) that are supported by the pier. This weight is

represented by the shaded area in figure 10.

Note that only one-half of the total live load is used in designing the foundation of a house; it would be exceptional for all of the floor area of the house to be fully loaded at the same time. (The total live load is used, however, for determining the size of girders and beams because the full load might be concentrated on any one of them.) One-half the total live load is also used for the roofs and walls of storage buildings. The total live load is used for stored items and floors of storage buildings.

Footing Area

A common fault in construction is to make the footings beneath the piers too small in relation to the footing beneath the exterior wall of the building.

To find how large a footing should be, it is necessary to know two things—the bearing value of your soil (p. 13) and the weight the footing will have to support.

In the farmhouse example, the wall load was 1,077 pounds per lineal foot. The pier load was 4,664 pounds per pier.

In table 1 you will find the width of footing required to bear the wall load and in table 2 you will find the size of footing required to bear the pier load. For example, if the soil bearing value is 1,000 pounds per square foot, the width of the wall footing must be 14 inches. The pier footing must be 27 inches square.

If the soil bearing value is 3,000 pounds per square foot, the wall footing can be less than 8 inches; however, a 12-inch footing will make construction easier. Because the 12-inch wall footing is larger than necessary, the pier footing must also be larger than necessary to equalize the bearing. Therefore, since a 12-inch wall footing will support approximately 2.8 times the wall load ($2.8 \times 1{,}077 = 3{,}016$ pounds per lineal foot), the pier footing must also be large enough to support 2.8 times the pier load ($2.8 \times 4{,}664 = 13{,}059$ pounds per pier). The pier footing would have to be 27 inches square.

If piers (rather than a continuous wall) are used under the perimeter of the building, the combined areas of the footings beneath the perimeter piers must equal the footing width shown in table 1 for a continuous wall multiplied by the length of the wall. For example, the necessary width of the wall footing for the farmhouse, on soil with a bearing value of 1,000 pounds per square foot, was 14 inches. On the 48-foot side of the house, the footing would have an area of 56 square feet. If six piers were used instead of the wall, the piers would have to have footing of 9.3 square feet each. The pier footings would measure about 3 feet 1 inch by 3 feet 1 inch.

Footing Thickness

Unreinforced footings must be at least 6 inches thick. If the footing projects 4 inches or more beyond the wall or pier, the footing thickness must be at least 1½ times the projection. For instance, if the footing under the 8-inch foundation wall of the farmhouse is 14 inches wide, it will project only 3 inches beyond

EXAMPLE 1: ESTIMATING WEIGHT OF A ONE-STORY FARMHOUSE

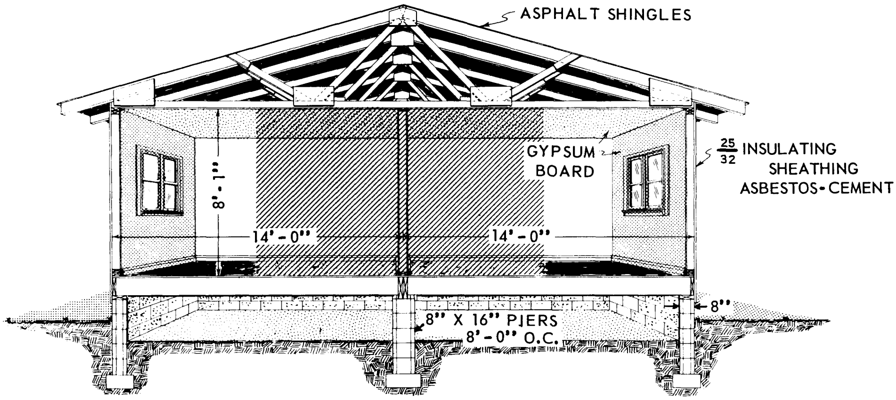

Figure 10.—A one-story farmhouse with a truss roof. The shaded area in the center of the house is the area supported by the piers under the center of the house.

Loads on Perimeter Foundation Walls

The following shows how to estimate the number of pounds of *dead load* per lineal foot of foundation wall:

	Thickness (inches)		*Pounds per inch of thickness*		*Number of square feet*		*Pounds per square foot*		*Pounds of dead load*
Roof	----		----		14	×	7	=	98
Ceiling	----		----		14	×	2	=	28
Stud wall	----		----		8	×	12	=	96
Floor	----		----		7	×	7	=	49
Foundation	8	×	12	×	4		----	=	384
Footing (estimated)	12	×	12	×	½		----	=	72
Total									727

The following shows how to estimate the number of pounds of *live load* per lineal foot of foundation wall:

	Number of square feet		*Pounds per square foot*		*Pounds of live load*
Roof	14	×	30	=	420
Floor	7	×	40	=	280
Total					700

The estimated load per lineal foot of foundation wall is figured as follows:

Total dead load $+ \frac{\text{total live load}}{2} =$ load per lineal foot or, $727+350=$ 1,077 pounds per lineal foot.

Loads on Interior Piers

Each pier supports 14 feet of the width of the house and 8 feet of the length—an area of 112 square feet.

The following shows how to estimate the number of pounds of *dead load* per pier:

	Thickness (inches)		*Pounds per inch of thickness*		*Number of square feet*		*Pounds per square foot*		*Pounds of dead load*
Interior wall	----		----		64	×	6	=	384
Floor	----		----		112	×	7	=	784
Pier	12	×	12	×	4		----	=	576
Footing (estimated)	27	×	12	×	2. 1		----	=	680
Total									2, 424

The following shows how to estimate the number of pounds of *live load* per pier:

The roof of the farmhouse is trussed and is supported entirely by the perimeter foundation walls. Therefore, the only *live load* bearing on the interior piers is the live load of the floor. Since each pier supports 112 square feet of floor, and floors have a live load of 40 pounds per square foot, the total live load on each pier is 4,480 pounds.

The estimated load per pier is figured as follows:

$$\text{Total dead load} + \frac{\text{total live load}}{2} = \text{load per pier or, } 2{,}424 + 2{,}240 = 4{,}664$$

pounds per pier.

EXAMPLE 2: ESTIMATING WEIGHT OF A POLE BARN

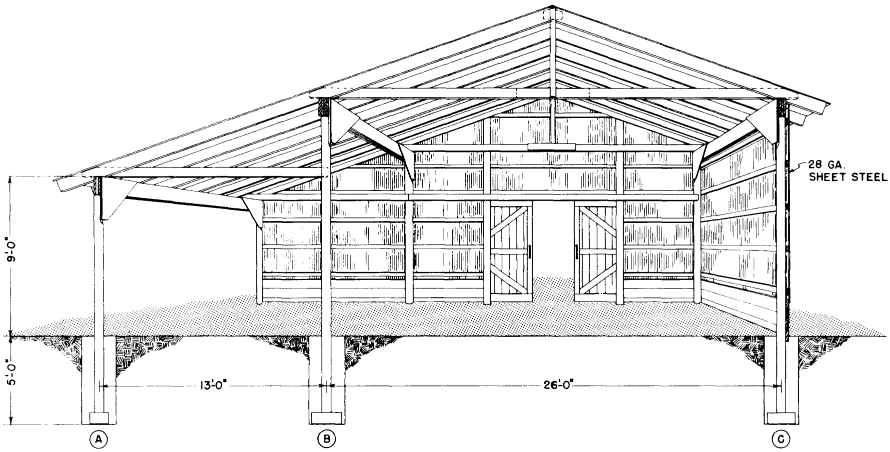

Figure 11.—A pole barn.

Loads on *A* Poles

Each *A* pole supports 6½ feet of the width of the roof and 16 feet of the length of the roof—an area of 104 square feet. The *A*-pole side of the barn is open so there is no siding load.

The following shows how to estimate the number of pounds of *dead load* per *A* pole:

	Number of square feet		*Pounds per square foot*	*Number of feet*		*Pounds per foot*		*Pounds of dead load*
Roof	104	×	4	------		------	=	416
Pole	------		------	13	×	11	=	143
Footing (estimated)	------		------	------		------	=	150
Total								709

The following shows how to estimate the number of pounds of *live load* per *A* pole:

The live load supported by an *A* pole is the live load on 104 square feet of roof at 20 pounds per square foot. The total live load per *A* pole is, then, 2,080 pounds.

The estimated load per *A* pole is figured as follows:

Total dead load + $\frac{\text{total live load}}{2}$ = load per *A* pole or, 709 + 1,040 = 1,749 pounds per *A* pole.

Loads on *B* Poles

Each *B* pole supports 19½ feet of the width of the roof and 16 feet of the length of the roof—an area of 312 square feet.

The following shows how to estimate the number of pounds of *dead load* per *B* pole:

	Number of square feet		*Pounds per square foot*	*Number of feet*		*Pounds per foot*		*Pounds of dead load*
Roof	312	×	4	------		------	=	1, 248
Pole	------		------	16	×	11	=	176
Footing (estimated)	------		------	------		------	=	250
Total								1, 674

The following shows how to estimate the number of pounds of *live load* per *B* pole:

The live load supported by a *B* pole is the live load on 312 square feet of roof at 20 pounds per square foot. The total live load per *B* pole is, then, 6,240 pounds.

The estimated load per *B* pole is figured as follows:

$\text{Total dead load}+\frac{\text{total live load}}{2}=\text{load per } B \text{ pole}$ or, $1{,}674+3{,}120=4{,}794$ pounds per *B* pole.

Loads on C Poles

Each *C* pole supports 13 feet of the width of the roof and 16 feet of the length of the roof—an area of 208 square feet. In addition to this, the *C*-pole side of the barn is sided with 28-gage corrugated steel. Each *C* pole supports an area of siding 16 feet high and 16 feet long, or 256 square feet of siding.

The following shows how to estimate the number of pounds of *dead load* per *C* pole:

	Number of square feet		*Pounds per square foot*	*Number of feet*		*Pounds per foot*		*Pounds of dead load*
Roof	208	×	4	------		------	=	832
Wall	256	×	2	------		------	=	512
Pole	------		------	16	×	11	=	176
Footing (estimated)	------		------	------		------	=	200
Total								1, 720

The following shows how to estimate the number of pounds of *live load* per *C* pole:

The live load supported by a *C* pole is the live load on 208 square feet of roof at 20 pounds per square foot. The total live load per *C* pole is, then, 4,160 pounds.

The estimated load per *C* pole is figured as follows:

$\text{Total dead load}+\frac{\text{total live load}}{2}=\text{load per } C \text{ pole}$ or, $1{,}720+2{,}080=3{,}800$ pounds per *C* pole.

TABLE 1.—*Safe total load, per linear foot, on wall footings*

Width of footing (inches)	Bearing area	Soil bearing value in pounds					
		1,000	2,000	3,000	4,000	6,000	8,000
	Square feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
8	0. 66	670	1, 340	2, 000	2, 670	4, 000	5, 340
10	. 83	835	1, 665	2, 500	3, 335	5, 000	6, 665
12	1. 00	1, 000	2, 000	3, 000	4, 000	6, 000	8, 000
14	1. 16	1, 165	2, 335	3, 500	4, 665	7, 000	9, 335
16	1. 33	1, 330	2, 670	4, 000	5, 330	8, 000	10, 670
18	1. 5	1, 500	3, 000	4, 500	6, 000	9, 000	12, 000
20	1. 67	1, 670	3, 335	5, 000	6, 670	10, 000	13, 340
22	1. 83	1, 835	3, 665	5, 500	7, 335	11, 000	14, 665
24	2. 0	2, 000	4, 000	6, 000	8, 000	12, 000	16, 000

TABLE 2.—*Safe total load on square pier footings*

Size of footing (inches)	Bearing area	Soil bearing value in pounds per square foot					
		1,000	2,000	3,000	4,000	6,000	8,000
	Square feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
12	1. 0	1, 000	2, 000	3, 000	4, 000	6, 000	8, 000
14	1. 36	1, 360	2, 720	4, 080	5, 440	8, 160	10, 880
16	1. 77	1, 780	3, 560	5, 340	7, 120	10, 680	14, 240
18	2. 25	2, 250	4, 500	6, 750	9, 000	13, 500	18, 000
20	2. 78	2, 780	5, 560	8, 340	11, 120	16, 680	22, 240
22	3. 37	3, 370	6, 740	10, 110	13, 480	20, 220	26, 960
24	4. 00	4, 000	8, 000	12, 000	16, 000	24, 000	32, 000
27	5. 06	5, 060	10, 120	15, 180	20, 250	30, 370	40, 500
30	6. 25	6, 250	12, 500	18, 750	25, 000	37, 500	--------
33	7. 55	7, 560	15, 120	22, 680	30, 240	45, 360	--------
36	9. 00	9, 000	18, 000	27, 000	36, 000	--------	--------
39	10. 56	10, 560	21, 120	31, 680	42, 240	--------	--------
42	12. 25	12, 250	24, 500	36, 750	--------	--------	--------

each side of the wall and must be 6 inches thick. The footings for the piers, however, were 27 inches square; if the piers are 12 inches square, the footings will project 7½ inches and will have to be at least 11½ inches thick.

Footings reinforced with steel do not have to be so thick, but their design should be referred to a structural engineer.

Footing Depth

Footing depths considered safe are given in table 3. They are based on recommendations made by the State agricultural colleges and are considered sufficient to prevent damage by frost but are not, necessarily, the total depth to which frost penetrates.

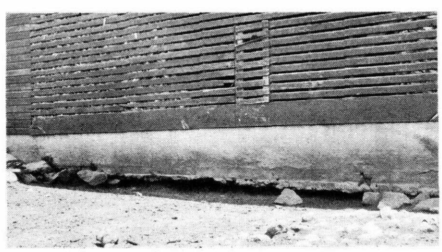

Figure 12.—A shallow foundation undermined by erosion.

These depths are given as a guide only; it is best to check with local building codes and with local engineers,.builders, or county agents.

The safe depth varies with the depth to which frost penetrates and the effect of frost on the soil. Great variations in frost depth can occur within a single state.

In any case, set the footings below the topsoil and on firm ground. If they are placed too close to the surface, rats can burrow under them, and wind and rain can erode the soil beneath them.

FOOTING CONSTRUCTION

Poured concrete is recommended for foundation footings for heavy buildings. Concrete fills up irregularities in the bed and arches over soft spots in the subsoil. Also, concrete footings provide a level and smooth surface for starting unit masonry foundations.

Two ½-inch reinforcing rods, spaced not more than 8 inches apart and running the length of the footing, should be embedded about 3 inches into the footing when the subgrade is not uniform.

Reinforcing is especially important at the corners of the footing. It will prevent cracking.

Large footings are more economical if they are made with reinforced concrete. The required thickness of reinforced concrete is less than the

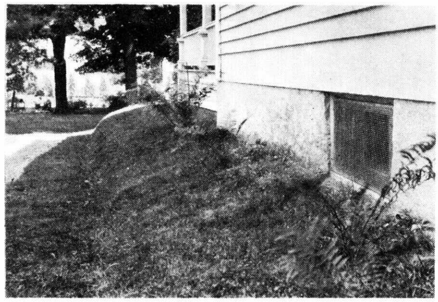

Figure 13.—A shallow foundation protected by a well-sodded earthbank.

required thickness of unreinforced concrete. Reinforced footings, however, require an engineer's advice.

Concrete can be saved by stepping (or corbelling) large, thick footings (fig. 14).

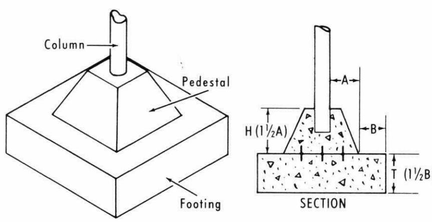

Figure 14.—Concrete can be saved by stepping footings and tapering pedestals. The thickness of each projection (*H*, *T*) must be at least 1½ times the distance it projects (*A*, *B*).

Sometimes in firm ground the trench is sloped out at the bottom and the footing is poured as part of the wall foundation. By doing this, separate footing construction is avoided.

If the foundation will be built of brick, concrete block, clay tile, or stone, the footing can be built of the same material. A bed of cement mortar (1 part cement; 3 parts sand), about 1 inch thick, is placed at the bottom of the trench

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If shallow footings are necessary because of soil conditions, the foundation must be protected against erosion beneath the footings. Bank soil against the foundation and sod or pave the banked soil.

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to smooth the subgrade and provide a bed to lay the first course (or row) of the footing.

Brick footings can also be corbelled. Start brick footings with a double course of brick at the base; steps may be made with each successive course. For heavy buildings, the steps are made in every second row—with the lower row being a stretcher row (bricks running the length of the wall) and the upper row a header row (bricks running across the wall).

A brick step should not be more than 2 inches wide over a header course and 1 inch wide over a stretcher course.

•

The footing must be bonded to the foundation.

Rods ½ inch in diameter and 8 to 10 inches long, spaced 16 inches apart, are embedded one-half their length in the footing. They project into the foundation wall above the footing when the foundation wall is built.

Rubble stone footings are bonded to the foundation walls by setting good-sized stones half their depth in the footing. These stones become part of the bottom row of rubble stone in the foundation wall. They should be spaced about 2 feet apart.

CONSTRUCTION PRACTICES

There is more to constructing a good foundation than knowing the correct footing size and selecting a suitable wall material. The building must be laid out, the excavation dug, the drainage tile installed, and the basement walls waterproofed. If all of these are done properly, you will save both time and money.

Building Layout

The first step in laying out a building foundation is clearing the site. Remove the sod. Remove all tree stumps from the site—they harbor termites and should not be used for fill or left under the building.

The second step in the building layout is the establishing of grade lines to keep the foundation true and level. Figure 15 shows the arrangement of batter boards and lines for a rectangular building.

Locate small stakes at each corner of the building. Indicate the outside line of the foundation wall with tacks driven in the stake tops. Measure the diagonals—the distance between stakes that are cater-corner from each other. If the diagonals are the same length, the corners are square.

Square the corners of the layout as follows: Measure along one end a distance in 3-foot units, and measure along an adjacent side the same number of 4-foot units. The diagonal of these distances will equal the same number of 5-foot units when the corner between the end and the side is square. For example, start at a corner and measure along the end of the building two 3-foot units (6 feet). Mark the distance with a small stake. Then measure from the same corner along one side of the building two 4-foot units (8 feet). Mark that distance with a small stake. Now if the corner from

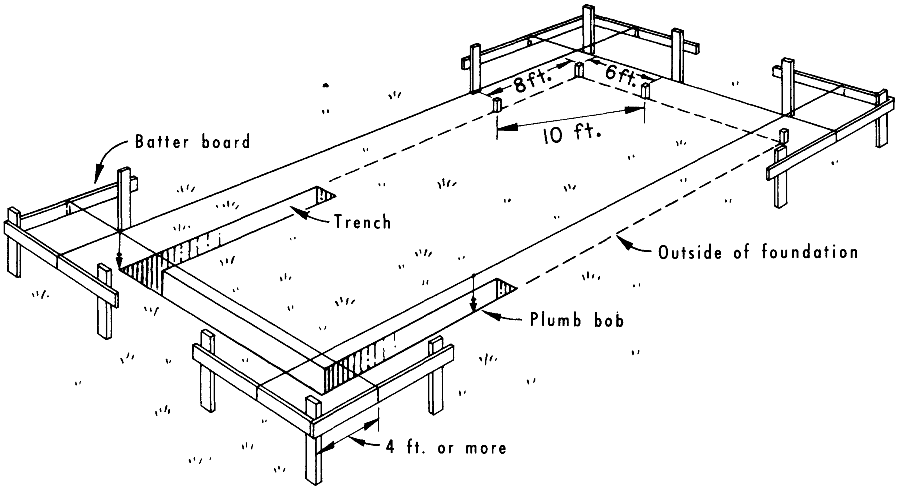

Figure 15.—Method of laying out a building.

which you began your measurements is square, the diagonal—or distance—between the two small stakes will be two 5-foot units, or 10 feet.

After you have located and squared the corners, drive three 2- by 4-inch stakes into the ground, 3 to 4 feet beyond each corner as shown in figure 15. Nail 1- by 6-inch boards (batter boards) horizontally to the stakes. The tops of the 1 by 6's must be level at the same grade. (Establish grade level with an engineer's level.) Fasten a twine, or stout string, line across the tops of opposite batter boards. Set the line over the tacks in the corner stakes with a plumb bob. Check the diagonals again to make sure the corners are square.

Excavation

Dig the general excavation only to the top of the footings or to the bottom of the fill under the basement floor.

Make the final excavation for footings when it is nearly time to pour the concrete; some soils become soft with exposure to air or water.

During the progress of the work, keep the excavation sloped to a low spot. Pump out any water that collects; do not let it saturate the whole area. Wet soil is difficult and costly to handle.

Deep excavations must be wide enough to work in when constructing and waterproofing the foundation wall. Where soil slides easily, it is sometimes more economical to make the excavation wider than it is to install forms, cribbing, or other braces. The general method of shoring up sliding soil, however, is illustrated in figure 16; this method can be adapted to most conditions.

Avoid handling the soil a second time. Spread as much soil as possible in its final position, and reserve only an amount sufficient for backfilling.

TABLE 3.—*Suggested depths for placing bottoms of footings*

[Figures in column A apply to milder areas; those in B to colder areas]

State	Light buildings		Farmhouse[1]		Heavy permanent barns and storage		Local considerations
	A	B	A	B	A	B	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	
Alabama	12	12	18	18	18	18	Reinforce footings and floor, and use piles in Blackbelt area.
Alaska	48 to 60	60 to 72	48 to 60	60 to 72	48 to 60	60 to 72	In nonpermafrost areas place polystyrene on outside of the foundation walls.
Arizona	12	20	18	36	18	36	Closeness of irrigation a factor.
Arkansas	12	12	16	16	18 to 24	18 to 24	Continuous foundations preferred.
California	6	12 to 18	8 to 12	18 to 24	12	24 to 30	
Colorado	12	18	18	24	18	24	Protect from roof water.
Connecticut	----------	(2) 24	----------	30 to 48	----------	30 to 48	
Delaware	18	24	24	30	30	30	Consult county building code.
Florida	surf	surf	surf	6 to 12	surf	6 to 12	Wide footings near surface; sandy soil.
Georgia	6	12	12 to 18	18	12 to 18	18	Conditions variable; seek local advice.
Idaho	12	18	24	36	36	48	Reinforce in wet cold locations.
Illinois	12	18	24	36	36	48	Reinforcement advised.
Indiana	18 to 24	18 to 24	24 to 36	24 to 36	36	36	
Iowa	18	20	36	42	36	42	
Kansas	24	24	60	60	48	48	Reinforce; heavy footings needed on swelling and shrinking soils.
Kentucky	18 to 24	18 to 24	18 to 24	30	30	30	
Louisiana	2 to 12	2 to 12	2 to 12	2 to 12	2 to 12	2 to 12	Wide footings on alluvial soils.
Maine[3]	48 to 60	60 to 72	48 to 60	60 to 72	48 to 60	60 to 72	
Maryland[4]	----------	----------	----------	----------	----------	----------	Conditions variable; seek local advice.
Massachusetts	24 to 48	24 to 48	24 to 48	24 to 48	24 to 48	24 to 48	Soil conditions fairly uniform.
Michigan	(4) 18	24	36	36	36	36	
Minnesota	12	18	60	60	(5) 18	(6) 36	
Mississippi	9	9	(7)	(7)	(7)	(7)	
Missouri	12	18	18	24	24	30	
Montana	18	18	44	44	30	40	Seek local advice.

Nebraska	12	18	18	24	18	24	Guard against roof water and rooting animals.
Nevada	0 to 6	18	0 to 6	18	12	24	
New Hampshire	36	48	72 to 96	72 to 96	48	72	Greater depth is for masonry.
New Jersey	6 to 8	24 to 30	16	36	[8] 16	[8] 36	
New Mexico	12	[4]	15 to 18	20 to 24	18 to 20	24 to 30	
North Carolina	12	12	12	18 to 24	12	18 to 24	
North Dakota	18	18	--	--	--	--	Reinforce.
Ohio	18	24	36	42	36	42	Do.
Oklahoma	12	18	18	24	24	24	Reinforce masonry for swelling, shrinking and heaving soil.
Oregon [11]	--	--	--	--	--	--	
Pennsylvania	36	--	48 to 72	48 to 72	48	48	
South Carolina	10 to 12	12	14	18	14	18	
South Dakota	18	18	54	54	24	24	For frame buildings use continuous foundations.
Do	42	42	60	60	48	48	For masonry buildings use continuous foundations.
Tennessee	12	12	24	24	24	24	Guard against termites.
Texas	12	20	20	30	30	34	
Vermont	12	12	60	60	60	60	Conditions vary widely; carry to firm soil.
Virginia	24	24	24	24	24	24	
Washington	--	--	--	--	--	--	Conditions variable; seek local advice.
West Virginia	18 to 24	24 to 30	18 to 24	24 to 30	24	30	
Wisconsin	30	42	36	48	[9] 36	[10] 42	
Wyoming	24	30	36	42	36	42	

[1] Where depth is 48 inches and over, basements are generally used.
[2] For temporary buildings.
[3] Use buttress on outside face of wall or use a footing; less depth is required in gravelly soils.
[4] For snow-protected ground.
[5] Wooden barns.
[6] Masonry barns.
[7] Depth to uniform soil.
[8] Footings for storage structures reinforced.
[9] 48 inches if building is unheated.
[10] 54 inches if building is unheated.
[11] Conditions vary (climate, elevation, soil and soil moisture) seek local advice.

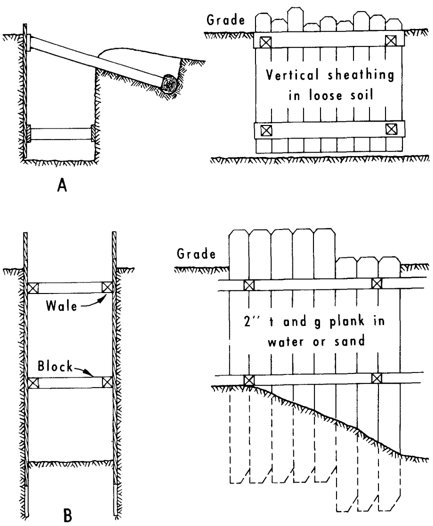

Figure 16.—A, Method of shoring fairly stiff or moist earth; *B*, method of sheet-piling sandy soil. If the excavations are deeper than 6 feet, or are very wet, the work can be done more safely and economically by experienced excavators.

Drainage

Draining water away, and keeping it away, from the foundation is important. Equip the building with gutters and downspouts to carry water from the roof. Grade the finished site for surface runoff, sod or pave the ground for about 10 feet around the building, and intercept and divert ground water from higher elevations.

The footings of houses with basements should be protected with drain tile. Use 4-inch agricultural drain tile; lay the tile just above the bottom of the footing. Slope the tile at least 1/8 inch per lineal foot and backfill over it with 18 inches of gravel. Make sure the tile outlet is unclogged and water will flow freely from the end of the tile to the ground surface or a sewer drain.

Drainage tile for a grade beam foundation is laid slightly differently. Lay it just outside the line of piers and 8 to 16 inches below the bottom of the grade beam. Slope the tile at least 1 inch in 20 feet, and outlet the low end on the ground surface. Install the tile after the piers and grade beam have set and cured.

Dampproofing

Dampproofing or waterproofing is least expensive—and most effective—if it is done to the exterior of the foundation wall at the time of construction.

Where the soil has only a moderate amount of moisture, or where the foundation drainage will not allow the water in the soil to build up pressure, it is usually enough to only dampproof the exterior of the foundation walls by applying two coats of hot coal-tar pitch.

A better dampproofing is the application of two coats of cement mortar, each 3/8 inch thick. The mortar is a mixture of 1 part portland cement (or 2/3 cement and 1/3 lime to accelerate setting) and 2 1/2 to 3 parts sand by volume. One cubic foot of mortar will cover 30 to 32 square feet of wall.

Both coats of mortar must cover the foundation wall from the top of the projection of the footing to several inches above grade at the top.

Before applying the mortar, clean the foundation wall thoroughly. Remove dirt, grease, oil, and loose particles of mortar or

Do not backfill against the waterproofing or dampproofing until the first floor of the building is in place. Any movement of the walls may crack the coating and cause it to leak.

concrete. Then moisten the wall surface.

The first coat of mortar should be scratched before it hardens. A board with nails driven through it, like a sharp rake, makes an excellent scratcher. Scratching is essential to make the second coat stick to the first coat.

Allow the first coat to harden for at least 24 hours. Then damp it down and apply the second coat. Keep the second coat damp for at least 48 hours.

The foundation can be further dampproofed by coating the cured mortar with hot coal-tar pitch. Twenty to 25 pounds of tar are needed to coat 100 square feet of wall.

FOUNDATION REPAIRING AND REMODELING

Foundation repairing or remodeling is frequently a hard job requiring the services of an engineer, builder, or house mover. Often it is necessary to lift the building from the existing foundation, and support the building in the air until the repair is completed. If an entire foundation is replaced, the new foundation must be expertly constructed to fit the building; if only part of a foundation is replaced, the new part must not only fit the building but be bonded to the rest of the foundation. Digging a basement

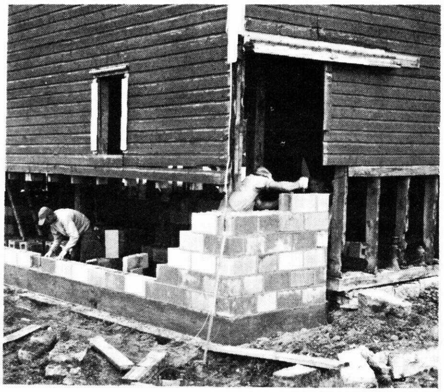

Figure 17.—Rotten sills and the lower end of the studs are being replaced. Note that the new foundation is being built in sections. This is safer and easier than replacing an old foundation all in one operation.

under a house usually means that the workmen have to work in cramped, close quarters. If the house has a chimney above the area of the new basement, the chimney will need special support to keep it from crashing down to the floor of the new basement.

Some foundation repair jobs are alike; others are one-of-a-kind situations. There are a few general pointers, however, that will make many of the jobs safer and easier undertakings.

Raising and Supporting Buildings

Before you raise a building, unload it. Remove heavy contents—hay, feed, machinery—and property that is easily damaged.

Next disconnect electric and telephone wires, plumbing, and masonry steps and porches. Remove the nuts from the bolts that anchor the sills to the foundation.

Make holes through the foundation walls near the original building

piers. Slip temporary sills—8- by 8-inch or 12- by 12-inch timbers—through the holes. The temporary sills must extend beyond the walls of the building far enough to be supported on cribbing.

Jack up the temporary sills. This will transfer the weight of the building from the foundation to the timbers.

Support the temporary sills on cribbing (or blocking) built out of 6 by 6's or 4 by 4's. Remove the jacks. Build the cribbing carefully so it will not rock or tip. Set it on firm, dry ground; 2- by 10-inch planks laid close together on the ground will serve as a footing and distribute the load of the cribbing.

When only a small part of the building is raised, post supports—wood 6 by 6's or 4 by 4's, or pipes—are often sufficient and less of an obstruction to work than temporary sills and cribbing.

If a sufficient number of jacks is not available to raise the whole building at one time, raise one side a little, set cribbing to hold the raised side in place, and progress around the building, raising each side by stages until the whole building is raised high enough to build the new foundation.

Masonry buildings should be raised only under the supervision of an experienced building or house mover.

Large buildings without cross partitions must have stiff diagonal braces inside to prevent them from collapsing, and long struts (or guy wires) outside to resist the wind.

Figure 18.—Set the cribbing so it will support the screw jack evenly and firmly on a broad base.

Rebuilding Masonry Foundation Walls

Masonry foundation walls of large buildings are safely and easily rebuilt if alternate sections 4 feet long and 8 feet apart are replaced one at a time.

Remove a 4-foot section of foundation wall and excavate to the bottom of the footing. Use the same construction methods for rebuilding the section that you would use for a new foundation.

The new footing can be stepped if the ground slopes, but each step of the footing must be level. Concrete is the best material for the footing; the foundation wall, however, will be more easily built from unit masonry.

- Never place a house jack where it can slip or tip when loaded.
- Prevent the jack gear from slipping or jamming by placing the jack on a solid, level base.
- Replace the jack with cribbing or pole braces as soon as possible.
- Never leave a jack loaded overnight. Never leave it loaded for any long period of time. Vibration, jolts, or wind can cause a jack to slip.

Adding a Basement

While it is usually poor economy to add a large basement to an existing house, a small basement—8 to 10 feet wide with sufficient space for a furnace—can be added without great cost or labor.

The further the basement is under the house, the greater the amount of work involved—so locate it near one outside foundation wall. If the basement will be used for heating-plant space, locate it so the chimney will be accessible from the basement.

Support the building girder, or sill, that spans the length of the basement with I-beams or heavy wood beams. These beams replace the piers that supported the building girder before the basement was dug. The ends of the supporting beams must rest in slots in the top of the new basement walls.

When you add a basement under an entire house, build it in sections. It is costly and hazardous to excavate a large basement under an existing building all at one time.

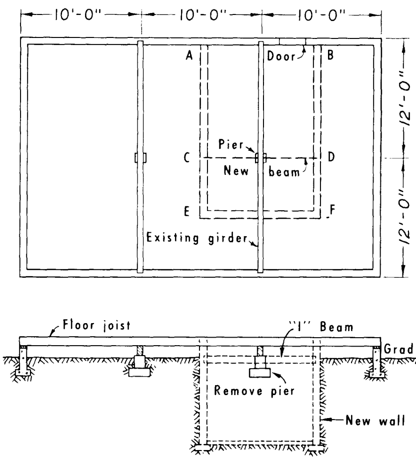

Figure 19.—When excavating a small basement, take care not to let sliding soil undermine nearby foundation piers or walls.

A safe distance must be allowed between basement walls and foundation walls that are parallel to them. If the basement wall is too close to the foundation wall, the pressure exerted on the soil by the foundation wall will be exerted laterally on the basement wall.

The safe distance depends on the type of soil and on the difference in vertical height between the footing of the foundation wall and the footing of the basement wall.

In loose, sandy soil, do not put the new basement wall closer to a parallel foundation wall than $1\frac{1}{2}$ feet for each vertical foot distance between the footings of the two walls. For example, if the new footing is 4 feet lower than the old footing, the foundation wall and the basement wall must be 6 feet apart.

The safe distance per vertical foot difference in damp clay is 2 feet; in mixtures of sand, dry clay, gravel,

and ordinary soil it is $1\frac{1}{2}$ feet; in decomposed rock, cinders, or ashes it is 1 foot. If the soil becomes very wet, greater distances will be necessary and will have to be determined by an engineer.

When the side walls of the basement are built and the building girders are supported on beams, excavate the basement. Remove the earth from the excavation through an opening in the foundation wall. This opening can later become an outside door to the basement.

Build the rear wall of the basement after the excavation is completed. If the foundation of the house is entirely of piers (with or without curtain walls on the perimeter of the house), four basement walls will be needed.

When a chimney is within the area of a new basement, it must be extended to below the basement floor. During the excavation it must be supported on two or three steel beams. Support the ends of the beams on cribbing.

The exact placing of the beams and cribbing will depend on the headroom and work area under the house. Ordinarily, holes are cut in the masonry of the chimney just above the footing and the beams are inserted through the holes and blocked up. The chimney is then extended to a new footing below the basement floor. After the new chimney extension is strong enough to support the weight of the existing chimney, the beams are withdrawn and the holes are filled.

When you extend piers to a lower level, support the building girders on blocking, tear out the old piers, and build new ones. Start with a footing below the basement floor and build up. Pipe or structural steel piers are easier to build than masonry piers.

When you extend a wall or chimney to a lower level with unit masonry, you will probably have to omit the top course of units on the extension because of the unevenness of the bottom of the old footing. You can fill this space with stiff concrete. A boxlike form will keep the concrete in place until it sets.

Figure 20 shows forms for poured concrete extensions. The projection of the footing is chiseled off plumb with the wall in 12- to

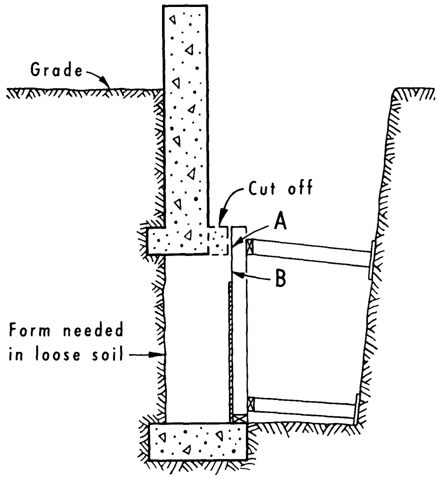

Figure 20.—When you extend a foundation, leave out the top boards of the form (at point *B*) until the concrete reaches the top of the highest board already in place; then put the top boards in place and pour the rest of the concrete. It may be necessary to mix this last concrete as a soft mortar and pour it through an opening (*A*) chiseled in the old footing.

18-inch sections, and the concrete is poured through the chiseled out sections.

Repairing Defects

Foundations usually settle excessively or unevenly when their footings are not deep enough to withstand frost heaving or erosion, or when the piers and walls have too little bearing area for the type of soil and building load. Settling may also be caused by rotted wood posts and sills, or by defective masonry.

Figure 21 illustrates a good method for increasing footing width. It is, however, more economical to relieve an overloaded foundation by installing extra piers than it is to increase the width of the existing footings.

If you add piers to your house foundation, make sure the sills and girders of the house actually rest on both the new and old piers. If the new piers settle a little when the building is lowered onto them, shim them with wedges of slate or flat pieces of hard tile. (Occasionally a pier is made about ½ inch higher than its final grade to allow for settling.)

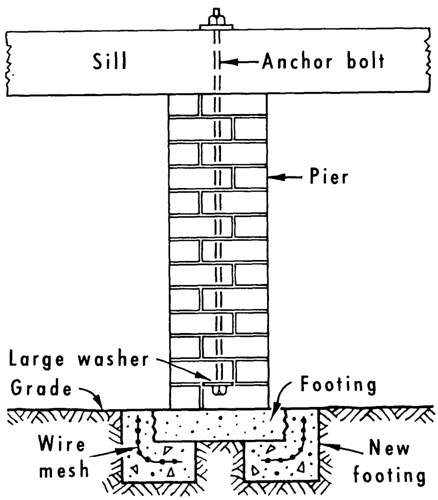

Figure 21.—A method of increasing the width of an existing footing. The load on the pier must be relieved until the new footing has hardened.

Piers and foundations that lean are difficult to plumb or push into place. Level the building with jacks and cribbing, and rebuild the foundation so that it will support the structure properly.

Where the soil under the footing is eroded but the foundation wall is not damaged, ram a mixture of damp—not wet—sandy clay and 5 to 8 percent (by volume) portland cement under the footing. This will provide a firm, secure bearing. Then bank soil against the foundation; bank it high enough for protection from frost. Slope the soil to divert surface and roof water, and pave or sod the banked soil to protect it from wind erosion.

Exposed wood usually deteriorates at joints first and causes metal fasteners to loosen. Remove loose spikes and driftbolts. Treat the holes and affected areas with a preservative. Plug the holes with wood dowels or with tar. Replace the spikes or bolts in new locations.

Cut away sections of unsound sills and replace them with plank patches. If the whole timber has been weakened, replace it.

Untreated wood posts rot rapidly at the ground line. Replace them with treated posts or with masonry

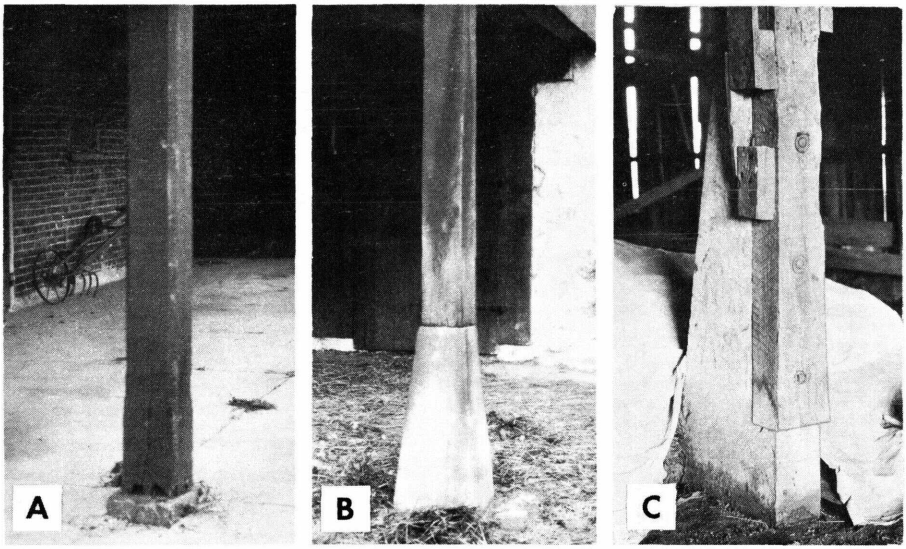

Figure 22.—*A*, Wood post that is rotten at the ground level; *B*, concrete pier replaces the rotten end of the post; *C*, precast stub post can also be used. The stub post is 8 by 8 inches at the top, 8 by 18 inches at the bottom, and 8 feet long. It is reinforced with six ⅞-inch twisted rods, and is bolted to the wood post with three ⅞-inch bolts.

piers. Figure 22, *C*, illustrates an effective method of repairing the lower end of a post with precast concrete.

Dampproofing

An existing basement can be temporarily dampproofed from the inside if the leaks are small and the water that penetrates the wall is not under pressure.

First plug the leaks; they are usually defective mortar joints. Cut the joints to a depth of ½ inch and tuck-point them with type N (1 part portland cement, 1 part type S lime, 6 parts sand) mortar.

After the leaks are plugged, plaster the wall with type M (4:1:15) mortar.

Cement-water paints and cement grouts, available commercially, are sometimes effective for dampproofing if the leaks are small and the water is not under pressure.

Moving Buildings

When you want to move a building to another site, hire a building mover—a specialist who knows the hazards involved and has the heavy equipment necessary to do the job right.

Don't build the foundation until the building has been moved to its new site and is jacked up on cribbing so the first floor is the desired height and the building is plumb.

A foundation built prior to moving a building may be damaged or may not fit the building. The building may be altered in shape or the opposite walls may not be exactly parallel or of equal length. Build the foundation, including the basement, in sections. There is less risk of damage.

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